9-01-00

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08/30/00 JC813 U.S. PTO

JC862 U.S. PTO 09/651421 08/30/00

UTILITY PATENT APPLICATION TRANSMITTAL	Attorney Docket No. **NAK-120**	Total Pages
	First Named Inventor **DALE BUERMANN**	
	Title **SIMULTANEOUS COMPENSATION OF SOURCE AND DETECTOR DRIFT IN OPTICAL SYSTEMS**	

APPLICATION ELEMENTS	ACCOMPANYING APPLICATION PARTS
1. [X] Fee Transmittal Form	8. [X] Assignment cover sheet and document(s)
2. [X] Specification Total Pages: [24]	9. [X] Power of Attorney by Assignee
3. [X] Drawing(s) Total Sheets: [5]	[ ] with CFR 3.73(b) statement
4. [X] Oath or Declaration Total Pages: [1]	10. [ ] English Translation Document
a. [X] Newly executed (original or copy)	11. [ ] IDS/PTO-1449
b. [ ] Copy from a prior application 1.63(d) (complete Box 17 and note Box 5 below)	[ ] with copies of cited references
i. [ ] Signed statement deleting inventors named in the prior application, see CFR 1.63(d)(2) and 1.33(b)	12. [ ] Preliminary Amendment
	13. [X] Return Receipt Postcard (MPEP 503)
	14. [X] Small Entity Statement
5. [ ] Incorporation by Reference (if 4b is checked) The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated therein by reference.	[ ] Statement filed in prior application Status still proper and desired
	15. [ ] Certified Copy of Priority Document(s) (if foreign priority is claimed)
	16. [ ] Other:
6. [ ] Microfiche Computer Program *(Appendix)*	
7. [ ] Nucleotide/Amino Acid Sequence Submission (all the following are necessary)	
a. [ ] Computer Readable Copy	
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[ ] continuation [ ] divisional [ ] CIP ...of prior application No.: [ ]

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09651421 083000

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(d)) – SMALL BUSINESS CONCERN

Application No.: not yet assigned
Filing Date: filed herewith
Applicant(s): Dale Buermann
Title: **Simultaneous Compensation of Source and Detector Drift in Optical Systems**

I hereby declare that I am the owner of, or an official empowered to act on behalf of, the entity identified below:

Name of Concern: **n&k Technology, Inc.**
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Patent Application

of

Dale Buermann

for

Simultaneous Compensation of Source and Detector Drift in Optical Systems

Field of the Invention

This invention relates to optical systems for performing measurements, and in particular to an apparatus and method for simultaneous compensation of drift occurring in a light source and in a light detector.

Background and Prior Art

In many fields optical measurement methods are preferred over other approaches because of their non-destructive nature and high accuracy. For example, measurements of reflected or transmitted light can be used to determine numerous physical properties of objects. In fact, optical measurements can be used to study the surface and the interior of objects or of the layers of which the objects are made. The basic physical parameters which can be derived from the study of reflected and transmitted light include thickness, index of refraction, extinction coefficient, surface roughness and energy bandgap of the material making up the object or of a particular layer of the object, e.g., the top layer. Other properties and information about the object and/or its layers, such as

material composition, mechanical condition, doping level etc. can be derived from these basic physical parameters.

The prior art teaches optical systems for performing optical measurements using light reflected and/or transmitted by the object being studied. Furthermore, methods for analyzing the reflectance and transmittance data, e.g., spectrum, polarization, intensity and other characteristics of the reflected or transmitted light are also known. For example, in U.S. Patent No. 4,905,170 Forouhi et al. describe an optical method for determining physical parameters of thin films based on reflectivity or transmittance data obtained over a range of wavelengths.

Further improvements in optical measurement and analysis techniques are frequently hampered by hardware problems. Specifically, light sources delivering the light incident on the samples are subject to intensity fluctuations. Also, light detectors positioned to receive the reflected or transmitted light are subject to fluctuations in detection sensitivity. These fluctuations are typically non-uniform across any given wavelength range and difficult to predict or unpredictable. They are caused by external influences such as temperature, pressure, humidity and operating conditions such as mechanical vibration, current, wear, aging and others.

Over time, source and detector fluctuations add up to produce source and detector drift. In general, the drift in the light source is not related to the drift in the light detector. Thus, in some cases the relative drift between source and detector can be the sum of the drifts.

Fig. 1 shows a simplified prior art optical measurement system **10** having a light source **16** for illuminating a test sample **12**

with a probe beam **18**, and a detector **20** for receiving a reflected beam **22**. Source **16** spans a certain wavelength range. The intensity I_s of beam **18** is graphed adjacent source **16** as a function of wavelength λ at an initial time t_o, e.g., at start-up, and at a later time t_1, e.g., after several minutes of operation. Likewise, the detection signal I_d of detector **20** is graphed adjacent detector **20** at times t_o and t_1. At time t_1 the source drift and detector drift are clearly significant and not correlated over the wavelength range. Hence, any calibration between source intensity I_s and detector signal I_d at time t_o can not be used for compensating the source and detector drifts at time t_1.

The prior art teaches to compensate for source drift in optical systems. For example, U.S. Patent No. 5,054,878 to John S. Gergely et al. teaches a device that automatically compensates for source light drift at the output end. In this invention, the output of the light source is coupled into a fiber optic, and a portion of the light output from the fiber optic is directed into a calibrated photodiode. The calibrated photodiode is connected to a transimpedance amplifier. The remainder of the light output by the fiber optic is focused into a test sample, and the light reflected from the test sample is measured using a detector. The signal detected at the detector is compared with the signal read at the transimpedance amplifier. To compensate for the drift in the light source, the signal from the transimpedance amplifier is divided into the signal from the detector.

The solution of Gergely et al. does not account for detector drift. In fact, most prior art solutions concentrate on stabilizing or compensating the light source by adjusting the external parameters and/or the operating conditions. For example, source intensity is often compensated by adjusting the

power supply (operating current) or varying the operating temperature (active heating and/or cooling). Meanwhile, detector drift is either assumed to be negligible and not taken into account or re-calibrated on an infrequent basis.

Advanced prior art optical measurement techniques, e.g., the Forouhi and Bloomer method, are very sensitive to drift. Hence, independent and uncorrelated drift in source and detector will prevent such techniques from yielding accurate values of physical parameters of test samples.

In addition, in some testing environments the optical measurement can not be interrupted to re-calibrate the source and/or the detector. This may be the case when the test sample is located in a controlled environment, e.g., a vacuum chamber, or when the measurement cycle is long and can not be halted. Under these conditions the optical measurement becomes progressively less accurate.

It would be an advance in the art to provide for simultaneous source and detector drift compensation without requiring that the measurement be stopped and without having to access the test sample.

Objects and Advantages

In view of the above, it is the object of the present invention to provide an apparatus and method for simultaneous source and detector drift compensation in optical systems. In fact, the object of the invention is to compensate for drifts occurring in the source and detector over time with minimal disruption to the optical system and without disturbing the test sample.

It is another object of the invention to provide an apparatus for source and detector drift compensation which can be used at

any time during a measurement cycle in an optical measurement system.

Yet another object of the invention is to provide a simple and inexpensive apparatus for drift compensation which is easy to use.

Further objects and advantages of the invention will become apparent upon reviewing the below specification.

Summary of the Invention

The objects and advantages of the invention are attained by a method for simultaneously compensating a source drift of a light source and a detector drift of a light detector. A first beam path is provided for a probe beam generated by the source and traveling from the light source to a test location. A second beam path is provided from the test location to the light detector. The beam paths are arranged to intersect or cross at a beam crossing.

A calibration sample is positioned at the test location and illuminated by the probe beam. In response, the calibration sample sends a known response beam along the second beam path to the light detector. The light source and the light detector are calibrated using this known response beam from the calibration sample. For compensation, a reference sample is placed at the beam crossing. The reference sample is positioned such that in response to illumination by the probe beam it sends a reference beam along the second beam path to the light detector. This reference beam is used to simultaneously compensate the source and detector drift. Conveniently, the calibration sample is a highly reflective sample of well-known reflectivity.

The compensation step can be repeated at any time by inserting the reference sample at the beam crossing after calibration of the light source and detector. The compensation is based on a relation established between the known response beam and reference beam. For example, the relation can be established based on the detector current intensities obtained while receiving the known response beam and the reference beam.

During testing a test sample is placed at the test location and illuminated by the probe beam. In response, the test sample sends a response beam along the second beam path to the light detector. In accordance with the invention, compensation of source and detector drift can be performed while the test sample is in place at the test location by inserting the reference sample at the beam crossing.

It is convenient when the reference sample is selected to have a particular response level to the probe beam. In particular, the intensity of the reference beam generated by the sample is preferably within a certain range of the intensity of the response beam from the test sample. It is also convenient when the probe and response beams are collimated at the beam crossing.

A system for simultaneously compensating source and detector drift in accordance with the invention includes the test location, the first beam path and the second beam path intersecting the first beam path at the beam crossing. Furthermore, the system has the calibration sample producing a known response beam to the probe beam and the reference sample for placing at the beam crossing. A first control unit, which controls the sensitivity of the detector, is used for calibrating the light source and detector using the response beam. A second control unit, which controls the intensity of

the light source, is then employed for compensating the source and detector drift using the reference beam. In fact, the first and second control units can be integrated in one control unit.

The light source can be any suitable light source spanning the desired wavelength range and can include incandescent bulbs, lasers and gas discharge tubes or any combination of such sources. For example, in measurements requiring reflectance or transmittance data in various portions of the spectrum, the source can be a broadband source made up of a laser and a discharge tube. Correspondingly, a broadband detector or a photospectrometer is chosen as the light detector.

Any known optical elements such as lenses, mirrors, gratings and other beam guiding elements can be used to guide probe and response beams between the source, test location and detector along their optical paths. When using broadband sources and detectors the use of reflective optics such as mirrors in the beam paths of probe and response beams in preferred to refractive optics. In one embodiment, the first beam path has a first mirror, such as a first toroidal mirror for guiding the probe beam. In fact, the first toroidal mirror collimates the probe beam to produce a collimated probe beam. A second toroidal mirror can be positioned to focus the collimated probe beam, e.g., into a fiber for delivery to the calibration sample or directly into the calibration sample. In another embodiment or in the same embodiment the response beam is collimated by a third toroidal mirror to produce a collimated response beam. The collimated response beam is then focused by a fourth toroidal mirrors on the detector. It is preferable that the beam crossing be between collimated probe and collimated response beams. It is further preferred that a first optical path length from the first toroidal mirror to the second

toroidal mirror and a second path length from the first toroidal mirror to the fourth toroidal mirror be equal.

Brief Description of the Figures

Fig. **1** is a simplified prior art optical measurement arrangement exhibiting source and detector drift.

Fig. **2** is a schematic view of an optical system according to the invention.

Fig. **3** is a schematic view of an embodiment of an optical system according to the invention using reflective optics.

Fig. **4** is a schematic view illustrating a portion of the optical system of Fig. 3.

Fig. **5** is a schematic view of another embodiment of the optical system according to the invention using refractive optics.

Fig. **6A** illustrates a portion of another optical system according to the invention.

Fig. **6B** illustrates a portion of still another optical system according to the invention.

DETAILED DESCRIPTION

Fig. 2 illustrates an optical system **50** for simultaneously compensating a source drift and a detector drift, which is used to measure physical properties of a test sample. As shown in Fig. 2, a calibration sample **52** is positioned at a test location and illuminated with a probe beam **54**. Probe beam **54** is generated by a light source **56**. Light source **56** can be a laser, a incandescent bulb, a gas discharge tube or any other light source capable of generating probe beam **54** of requisite characteristics. In many applications, probe beam **54** has to span a particular wavelength range $\Delta\lambda$. When wavelength range $\Delta\lambda$ is large, several light sources may be combined to form a broadband source.

Probe beam **54** propagates from light source **56** to calibration sample **52** along a first optical beam path **58**. Any number of optical elements such as lenses, mirrors, gratings and other beam guiding elements can be used in beam path **58** to guide probe beam **54** to calibration sample **52**. In the present embodiment a focussing lens **60** is positioned in beam path **58** to focus probe beam **54** on calibration sample **52**.

Upon illumination with probe beam **54** calibration sample **52** generates a known response beam, which is used for calibrating the light source **56** and the detector **68**. Depending on calibration sample **52** and probe beam **54**, the known response beam can be a reflected beam **62**, a transmitted beam **64** or both. Thus, either or both beams **62**, **64** can be treated as the response beam. Calibration sample **52** typically is a silicon sample whose reflection characteristics are well-known (e.g., can get from literature or measurement on another device). In the present discussion we will first treat only reflected beam **62** as the response beam.

Reflected beam **62** propagates along a second optical beam path **66** from calibration sample **52** to a light detector **68**. Light detector **68** can be any suitable light sensitive device such as a photodetector, a charge coupled device, a phototransistor, a spectrophotometer or any other photosensitive device. When source **56** is a broadband source then detector **68** is preferably a broadband detector, e.g., a spectrophotometer, sensitive to light spanning the entire wavelength range $\Delta\lambda$.

Second beam path **66** is arranged such that it crosses first beam path **58** at a beam crossing **70**. In other words, probe beam **54** and response beam, in this case reflected beam **62**, are guided such that they cross at beam crossing **70**. This can be

accomplished by using any suitable beam guiding elements in beam paths **58**, **66**. In this embodiment a mirror **72** is used in second beam path **66** to re-direct reflected beam **62** such that it crosses probe beam **54** at beam crossing **70**. Also, a focussing lens **74** is also positioned in second beam path **66** for focussing reflected beam **62** on detector **68**. It will be clear to a person skilled in the art that optical elements used in beam paths **58**, **66** to produce beam crossing **70** and properly guide probe and response beams **54**, **62** will depend on the geometry of optical system **50**.

When transmitted beam **64** is used as the response beam two planar mirrors **76**, **78** guide transmitted beam **64** to cross probe beam **54** at beam crossing **70**. Also, a focusing lens **86** is positioned between two planar mirrors **76**, **78** for preventing the divergence of the transmitted beam **64**. Again, a person skilled in the art will recognize that the optical elements to cross transmitted beam **64** with probe beam **54** at beam crossing **70** will depend on the geometry of optical system **50**.

A removable reference sample **80** indicated in a dashed line is positioned at beam crossing **70**. Preferably, a mechanical or an electro-mechanical unit (not shown) is used to place reference sample **80** at beam crossing **70** and remove it during measurement of a test sample. Reference sample **80** is a reflective sample over an entire wavelength range $\Delta\lambda$ of probe beam **54**, and when in place at beam crossing **70** it reflects probe beam **54** to detector **68**. The reflectivity R of the reference sample **80** is high enough to get a signal. For example, when probe beam **54** spans a wavelength range from 120 nm to 2000 nm reference sample **80** is a quartz sample exhibiting a nearly uniform 100% reflectivity over this wavelength range. Furthermore, the reflectivity of reference sample **80** can be closed to that of

remainder of optical system **50** for dynamic range purpose within a predetermined range.

Calibration sample **52** positioned at the test location is held on a stage **82**, of which only a portion is shown. Stage **82** enables calibration sample **52** to be moved or scanned as indicated by arrow A. In fact, stage **82** can be of the type permitting displacement of calibration sample **52** in any desired direction. In some embodiments calibration sample **52** is kept in a controlled environment, e.g., in a vacuum chamber. In these cases stage **82** will exhibit the necessary adaptations, as is known in the art.

First control units **84** is connected to detector **68** for controlling the detection sensitivity over wavelength range $\Delta\lambda$. Second control unit **88** is connected to light source **56** for controlling the light intensity over wavelength range $\Delta\lambda$. In particular, control units **84** and **88** have suitable amplification stages (not shown) to perform these adjustments. Alternatively, control units **84** and **88** can be connected to control mechanisms of source **56** and detector **68** respectively. In yet another embodiment, additional tuning and/or adjustment devices can be used to control the intensity of light source **56** and sensitivity of detector **68**. In fact, any approaches to controlling source intensity and detection sensitivity known in the art can be employed. Alternatively, first and second control units **84** and **88** can be integrated in one control unit **90**.

To calibrate the light source **56** and the detector **68**, optical system **50** is first operated with the reference sample **80** removed from beam crossing **70**. Calibration sample **52** is a reflective sample over wavelength range $\Delta\lambda$and has a known reflectivity R, such as silicon wafer. For example, the

reflectivity R of silicon sample **52** is about 50% from 120 nm to 2000 nm (refer to a graph of reflectivity as a function of wavelength λ in Fig. 2).

In the present embodiment light source **56** delivers probe beam **54** covering wavelength range $\Delta\lambda$ and calibration sample **52** has a reflectivity R of approximately 100% across that wavelength range. In most cases, however, reflectivity R will vary as a function of wavelength λ; $R=R(\lambda)$. The intensity I_s of probe beam **54** is variable over wavelength range $\Delta\lambda$. In other words, I_s of probe beam **54** is also a function of wavelength λ; $I_s=I_s(\lambda)$. Detector **68** is sensitive to light spanning wavelength range $\Delta\lambda$. However, the response of detector **68** is assumed to be linear since the response may differ with λ, but current to number of photon is linear.

When probe beam **54** is turned on it propagates along first beam path **58** and is incident on calibration sample **52**. In response, calibration sample **52** sends a known response beam in reflected beams **62** along the second beam path **66** to the light detector **68**. Since the reflectivity of calibration sample **52** is R, the following relationship exists between intensity I_s and detection signal I_d:

$$I_d=[R + \gamma(\lambda)]I_s,$$

where $\gamma(\lambda)$ is conditioned by system **50** and in particular the optical components in first and second beam paths **58** and **66**. The entire spectrum of light of the known response beam is used for calibrating the light source **56** and the detector **68**.

Control unit **84** now performs a relative calibration of source **56** and detector **68** by adjusting the sensitivity of the detector **68**. Adjusting the intensity of detector **68** is preferable

because turning up the light source **56** will alter a gain across the spectrum at different rates. However, if the light source **56** is a narrow band source, e.g., single λ value, adjusting the intensity of the light source **56** is also preferable. Also, either of the detector **68** and the light source **56** should not be adjusted after baseline is set. Furthermore, control unit **84** is not necessary for some applications. The relative calibration of source **56** and detector **68** is performed by adding a "δR" value to the data to maintain the ΔR value between the known response beam and reference beam, which is shown in the graph with respect to Fig. 2

Thus, relative calibration establishes a linear relationship between intensity value I_s and corresponding detection signal I_d across entire wavelength range $\Delta\lambda$.

During regular operation a test sample **52A** (shown in dashed line) is positioned in the place of calibration sample **52**, e.g., at the test location on stage **82**, and the response beam, i.e., either reflected beam **62** or transmitted beam **64** (or both), is detected by detector **68**. The data obtained from the response beam is used to analyze the physical properties of test sample **52** in accordance with any suitable technique known in the art. Furthermore, this method can be used to study the reflectivity characteristics of all the optical components in optical system **50** by operating this optical system without a test sample in place and with a 100% reflectivity test sample in place.

After a set time period or whenever drift of source **56** and/or detector **68** affects the measurement process, reference sample **80** is placed at beam crossing **70** while the test sample **52** is in place at the test location. As a result, probe beam **54** is reflected directly to detector **68** through lens **74**. The

reference sample **80** sends a reference beam along the second beam path **66** to the light detector **68** in response to illumination by the probe beam **54**. This reference beam is used to simultaneously compensate the source and the detector drift of the optical system **50**. The compensation step can be repeated at any time by inserting the reference sample **80** at the beam crossing **70** after calibration of the light source **56** and detector **68** using calibration sample **52**. The compensation is based on a relation established between the known response of calibration sample **52** and reference beam of reference sample **80**. For example, the relation can be established based on the detector current intensities obtained while receiving the known response beam and the reference beam.

Now a simultaneous compensation of source **56** and detector **68** drifts is performed by control unit **88** to re-establish the relative calibration. Intensity I_s of source **56** can be adjusted to re-establish relative calibration. It should be noted that this re-calibration or re-establishment of relative calibration accounts simultaneously for both source and detector drifts, although no absolute calibration is achieved.

A preferred embodiment of an optical system **100** according to the invention is illustrated in Fig. 3. In this embodiment a light source **102** is an integrated source having a gas discharge tube **104** and a laser **106** for spanning a wide wavelength range $\Delta\lambda$.

A first beam path **108** for a probe beam **110** emitted from source **102** and coupled to an optical fiber **144** has a first toroidal mirror **112** and a second toroidal mirror **114**. First toroidal mirror **112** collimates probe beam **108** to produce a collimated probe beam **109**. Second toroidal mirror **114** focuses collimated probe beam **109** into an optical fiber **116**.

Optical fiber **116** guides probe beam **110** to a focussing lens **118** which focuses probe beam **110** on a calibration sample **120**. Calibration sample **120** reflects a portion of the incident light from probe beam **110** in the form of reflected beam **122**, which is the response beam in this embodiment.

Response beam **122** is guided along a second beam path **128** from calibration sample **120** to a light detector **130**. In particular, response beam **122** is focussed by a focussing lens **124** into an optical fiber **126**. Optical fiber **126** guides response beam **122** to a third toroidal mirror **132** which collimates response beam **122**. Thus, a collimated response beam **123** is reflected from third toroidal mirror **132** to a fourth toroidal mirror **134**. Fourth toroidal mirror **134** focuses response beam **122** into an optical fiber **142** on detector **130**.

An integrated control unit **136** connected to detector **130** and to light source **102** controls these to obtain relative calibration and to re-establish the relative calibration during regular operation of testing a test sample in the manner discussed above. To re-establish relative calibration during operation, a reference sample **138** is placed at a beam crossing **140** between probe beam **110** and response beam **122**. In fact, beam crossing **140** is actually between collimated probe beam **109** and collimated response beam **122**. This location of beam crossing **140** is advantageous because angle θ_r is nearly the same for the whole beam whereas a non-collimated beam has different θ_r (as shown in Fig. 6). In addition, this location of beam crossing **140** is better for imaging point to point, e.g., for imaging source **102** into fiber **116** and fiber **126** into detector **130**.

The use of optical fibers **116** and **126** in guiding probe beam **110** and response beam **122** is advantageous due to the mechanical

flexibility optical fibers. This flexibility permits the user to alter the arrangement of optical system **100** with minimal effort and in short time.

A further advantageous aspect optical system **100** is illustrated in the partial view of Fig. 4. Here the re-establishment of relative calibration between source **102** and detector **130** is being effectuated while reference sample **138** is in place at beam crossing **140**. The optical path length between first toroidal mirror **112** and second toroidal mirror **114** is equal to L_1+L_3. The optical path length from first toroidal mirror **112** to second toroidal mirror **114** is equal to L_1+L_2. It is preferable that $L_2=L_3$ such that the optical path lengths from first to second toroidal mirrors and from first to fourth toroidal mirrors are equal. In this manner any effects of system **100** on the propagation of probe beam **110** are factored out.

A further advantage optical system **100** resides in its usage of toroidal mirrors. This is especially important when $\Delta\lambda$ is very large since chromatic effects are thus minimized.

Fig. 5 illustrates another embodiment of an optical system **200** according to the invention. System **200** uses refractive optics in the form of lenses **202**, **204** in a first optical beam path **206**. Lens **202** collimates a probe beam **208** emerging from a light source **210** to produce a collimated probe beam **209**. Lens **204** focuses collimated probe beam **209** into an optical fiber **212**. Fiber **212** delivers probe beam **208** to a focusing lens **214**, which guides probe beam **208** to a calibration sample **216**.

A response beam **218** in the form of reflected beam propagates from calibration sample **216** along a second optical beam path **220** and is in-coupled into an optical fiber **222**. In fact,

focusing lens **214** focuses probe beam **208** such that response beam **218** is in-coupled into fiber **222**. Fiber **222** delivers response beam **218** to a second set of refractive optics in the form of lenses **224** and **226**. These lenses collimate response beam **218** to a collimated response beam **219** and focus it on a detector **228** respectively.

As in the embodiment of Figs. 3 and 4, optical system **200** has a beam crossing **230** between collimated probe and response beams **209** and **219**. A reference sample **232** is placed at beam crossing when calibration is required.

Optical system **200** has a control unit consisting of several independent devices. In particular, a processor **234** connected to thermal control **236**, a level tuner **238** and a power supply **240** constitute the control unit in this embodiment. During calibration processor **234** can adjust the sensitivity of detector **228** or its detector signal I_d with the aid of level tuner **238**. Alternatively, or in conjunction, processor **234** can adjust the source intensity I_s by changing the drive current of light source **210** via power supply **240**. If required, processor **234** can change the operating temperature of light source **210** with the aid of thermal control **236** to further tune source intensity I_s. More particularly, thermal control **236** is connected to a Peltier device **242** which cools or heats light source **242** depending on the signal from thermal control **236**.

Optical system **200** of Fig. 5 can be used when $\Delta\lambda$ is not very large. Also, it can be used when very precise control of detector **228** and light source **240** is required.

Another embodiment of the invention is shown in the partial view of Fig. 6A. In this case a probe beam **300** emitted from a light source **302** is focussed into a first fiber **304** by a first

toroidal mirror **306**. Also, a second toroidal mirror **308** is used to focus a response beam **310** returning from the calibration sample (not shown) via a second fiber **312** on a detector **314**. A reference sample **316** is placed at a beam crossing **318** between probe and response beams **300**, **310**. As indicated above, non-collimated beams **300**, **310** have different θ_r.

Yet another alternative embodiment using refractive optics in the form of lenses **400** and **402** is shown in Fig. 6B. A probe beam **404** emitted from a light source **406** is focussed by lens **400** into a first fiber **408**. First fiber **408** delivers probe beam **404** to a calibration sample (not shown). A response beam **410** returning from the calibration sample via second fiber **412** is focused by lens **402** on detector **414**. A reference sample **416** is positioned at a beam crossing **418**.

Optical systems in Figs. 6A and 6B have fewer elements, thus lower cost of manufacturing.

It will be clear to one skilled in the art that the above embodiments may be altered in many ways without departing from the scope of the invention. Accordingly, the following claims and their legal equivalents should determine the scope of the invention.

CLAIMS

What is claimed is:

1. A method for simultaneously compensating a source drift of a light source and a detector drift of a light detector, said method comprising:
   a) providing a first beam path for a probe beam traveling from said light source to a test location;
   b) providing a second beam path from said test location to said light detector such that said second beam path crosses said first beam path at a beam crossing;
   c) positioning at said test location a calibration sample for sending a known response beam along said second beam path to said light detector in response to said probe beam;
   d) calibrating said light source and said light detector using said known response beam;
   e) placing a reference sample at said beam crossing for sending a reference beam along said second beam path to said light detector in response to said probe beam;
   f) simultaneously compensating said source drift and said detector drift using said reference beam.

2 .The method of claim 1, wherein said step of simultaneously compensating comprises establishing a relation between said known response beam and said reference beam.

3 The method of claim 1, further comprising placing a test sample at said test location such that said test sample sends a response beam along said second beam path to said light detector in response to said probe beam.

4. The method of claim 3, wherein said step of placing said reference sample at said beam crossing and said step of simultaneously compensating are performed while said test sample is at said test location.

5. The method of claim 1, wherein said calibration sample is a reflective calibration sample having a well-known reflectivity.

6. The method of claim 1, wherein said reference sample is selected such that the intensity of said reference beam is within a predetermined range of the intensity of said response beam.

7. The method of claim 1, further comprising the step of collimating said probe beam and said response beam at said beam crossing.

8. A system for simultaneously compensating a source drift of a light source and a detector drift of a light detector, said system comprising:

a) a test location;

b) a first beam path from said light source to said test location;

c) a second beam path from said test location to said light detector;

d) a beam crossing between said first beam path and said second beam path;

e) a calibration sample for positioning at said test location and for sending a known response beam along said second beam path to said light detector in response to said probe beam;

f) a first control unit for calibrating said light source and said light detector using said known response beam;

g) a reference sample for placing at said beam crossing for sending a reference beam along said second beam path to said light detector in response to said probe beam; and

h) a second control unit for simultaneously compensating said source drift and said detector drift using said reference beam.

9. The system of claim 8, further comprising a test sample for positioning at said test location for sending a response beam along said second beam path to said light detector in response to said probe beam.

10. The system of claim 9, wherein said reference sample is selected such that the intensity of said reference beam is within a predetermined range of the intensity of said response beam.

11. The system of claim 8, wherein said calibration sample is a silicon sample.

12. The system of claim 8, wherein said light source is selected from the group of light sources consisting of incandescent bulbs, lasers, and gas discharge tubes.

13. The system of claim 8, wherein said light source is a broadband light source.

14. The system of claim 8, wherein said light detector is selected from the group of light detectors consisting of broadband light detectors and photospectrometers.

15. The system of claim 8, wherein said calibration sample is reflective calibration sample having a

well-known reflectivity.

16. The system of claim 8, further comprising a first toroidal mirror positioned in said first beam path.

17. The system of claim 16, further comprising a second toroidal mirror, said first toroidal mirror being positioned to collimate said probe beam to produce a collimated probe beam, said second toroidal mirror being positioned to focus said collimated probe beam.

18. The system of claim 8, further comprising a third toroidal mirror positioned in said second beam path.

19. The system of claim 18, further comprising a fourth toroidal mirror, said third toroidal mirror being positioned to collimate said response beam to produce a collimated response beam, said fourth toroidal mirror being positioned to focus said collimated response beam.

20. The system of claim 19, further comprising a first toroidal mirror positioned to collimate said probe beam to produce a collimated probe beam, and a second toroidal mirror being positioned to focus said collimated probe beam, said collimated probe beam crossing said collimated response beam at said beam crossing.

21. The system of claim 20, wherein a first optical length from said first

toroidal mirror to said second toroidal mirror equals a second optical length from said first toroidal mirror to said fourth toroidal mirror passing through said beam crossing.

22. The system of claim 8, further comprising at least one lensing element positioned in said first beam path.

23. The system of claim 8, further comprising at least one lensing element positioned in said second beam path.

24. The system of claim 8, further comprising at least one optical fiber in said first beam path.

25. The system of claim 8, further comprising at least one optical fiber in said second beam path.

Abstract of the Disclosure

An optical system for simultaneously compensating a source drift of a light source and a detector drift of a light detector includes a test location, a first beam path from the light source to the test location, a second beam path from the test location to the light detector. First and second beam paths are arranged to intersect at a beam crossing. A calibration sample having a known reflectivity is positioned at the test location and illuminated by a probe beam generated by the light source. A known response beam of the calibration sample is used for calibrating the light source and the detector. A reference sample is placed at the beam crossing and illuminated by the probe beam. In response, the reference sample sends a reference beam along the second path length, which is used for compensating the source and detector drift.

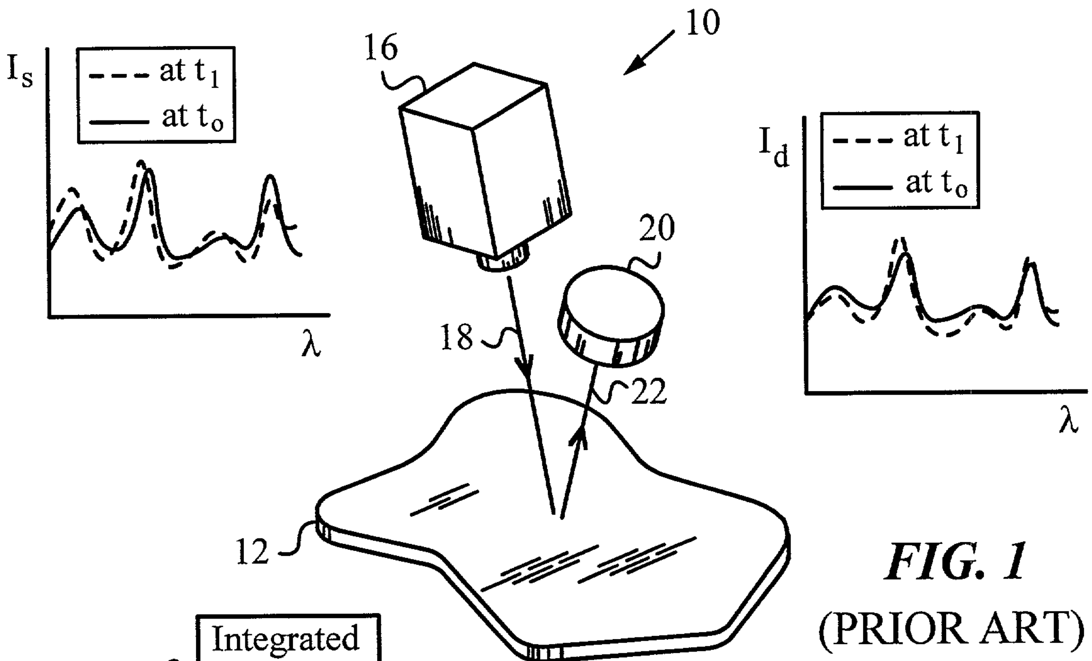

FIG. 1
(PRIOR ART)

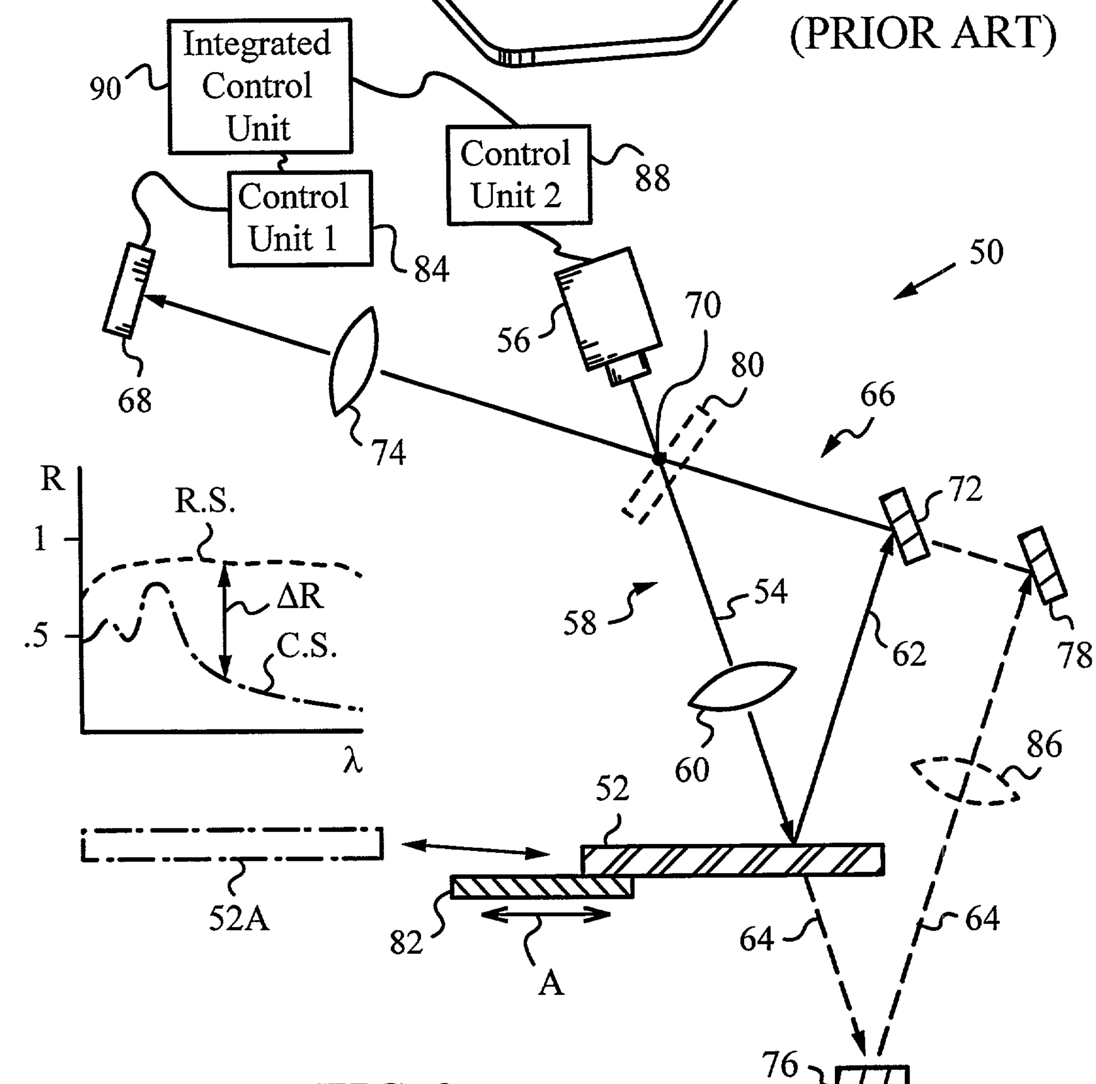

FIG. 2

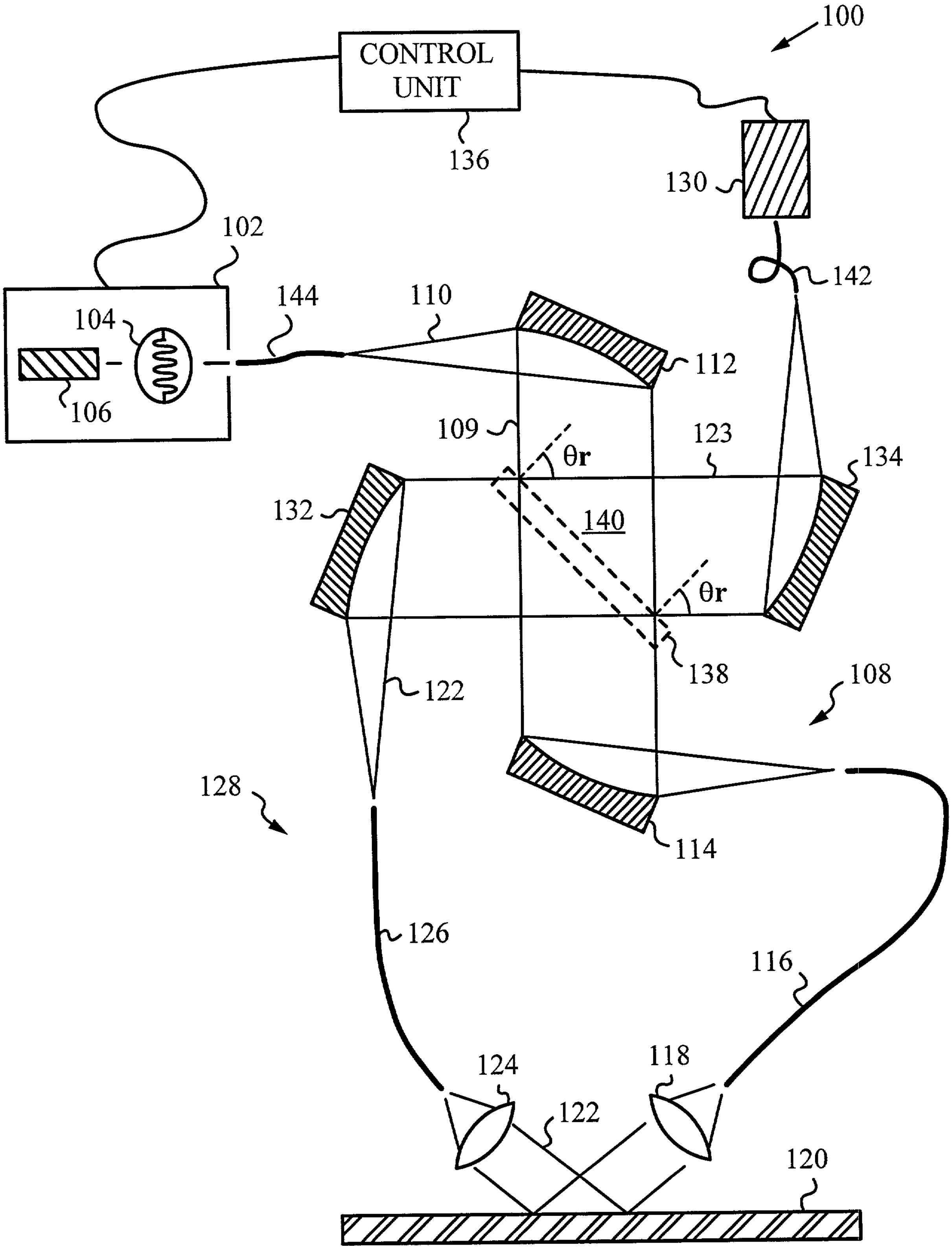
100
CONTROL UNIT
136
130
142
102
104
106
144
110
112
109
θr
123
134
132
140
θr
138
122
108
128
114
126
116
124
118
122
120

FIG. 3

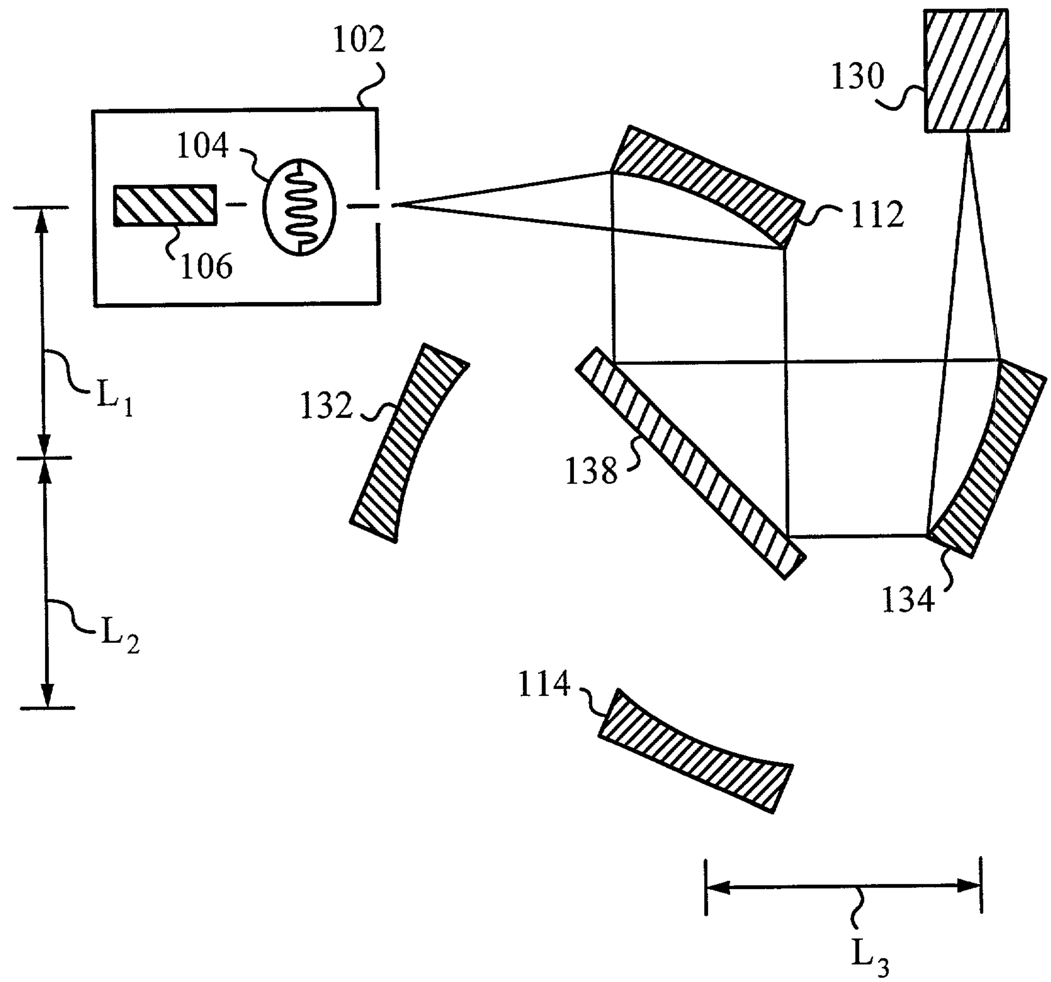

FIG. 4

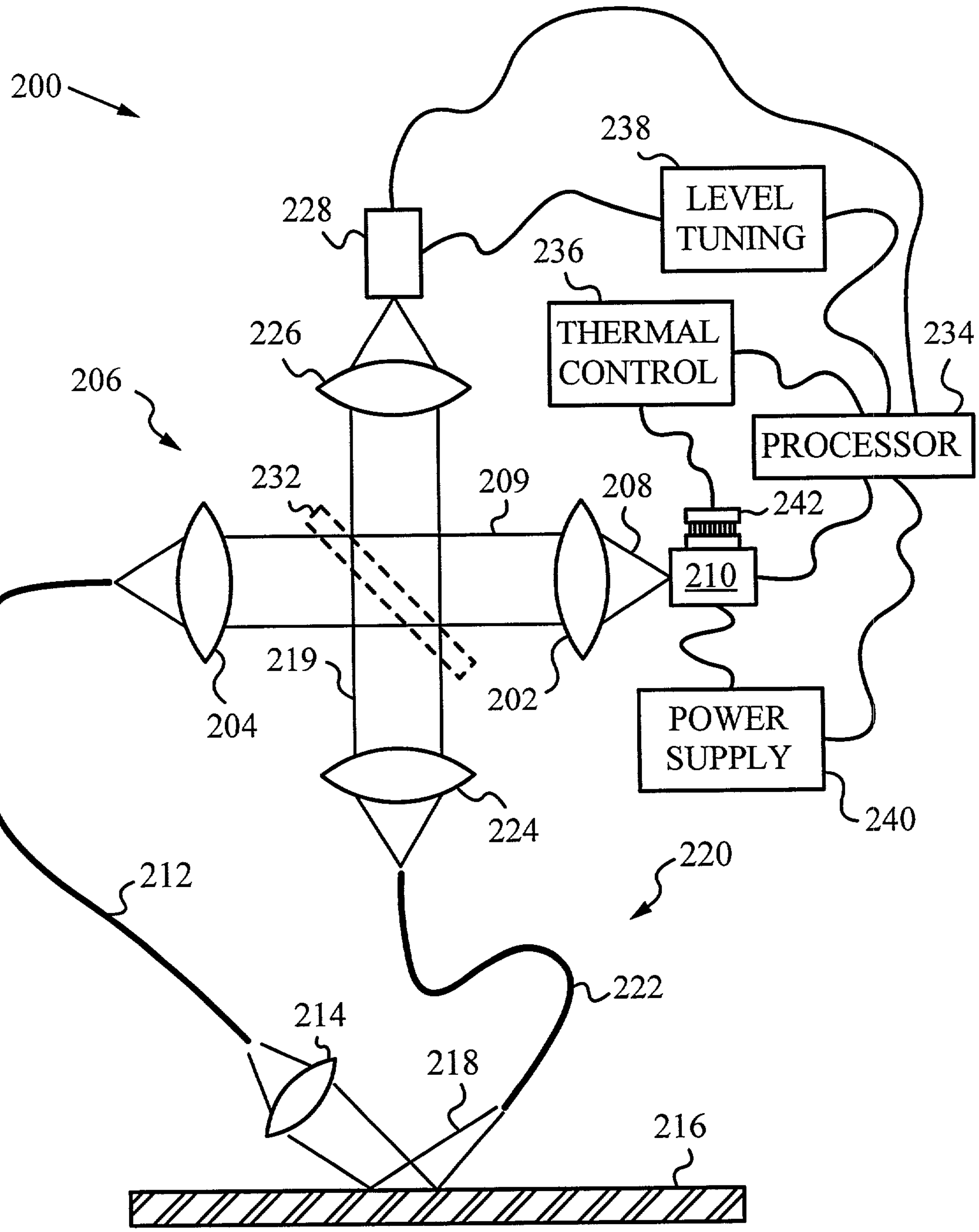
200
238
LEVEL TUNING
228
236
THERMAL CONTROL
226
234
206
PROCESSOR
232
209
208
242
210
219
202
204
POWER SUPPLY
224
240
220
212
222
214
218
216

FIG. 5

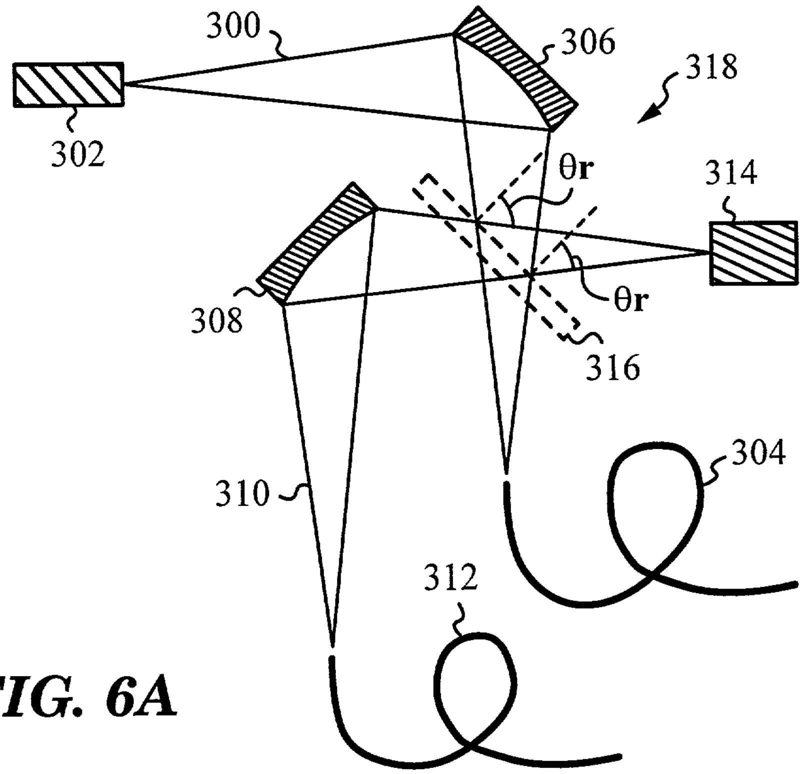
300
306
318
302
θr
314
308
θr
316
304
310
312

FIG. 6A

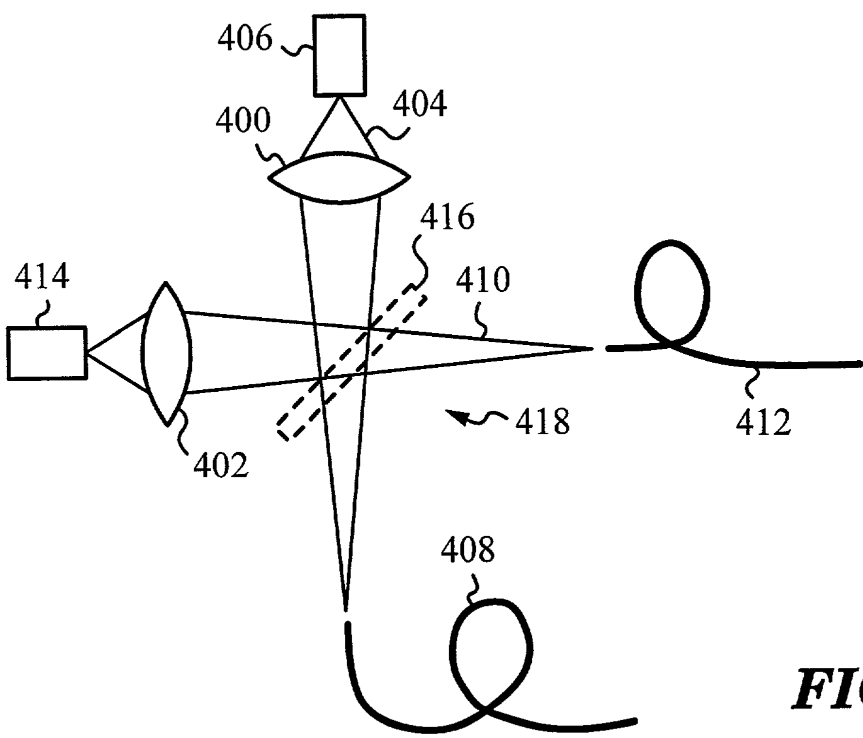
406
400
404
416
414
410
418
412
402
408

FIG. 6B

Attorney Docket: **NAK-120**

Declaration for Patent Application and Power of Attorney

As a below named inventor, I hereby declare that my residence, post office address, and citizenship are as stated below next to my name, and that I believe I am the original, first and sole inventor (if only one is listed) or an original, first and joint inventor (if plural names are listed) of the subject matter which is claimed and for which a patent is sought on the invention described in the attached specification entitled **Simultaneous Compensation of Source and Detector Drift in Optical Systems.**

First or Sole Inventor:	Full name:	**DALE BUERMANN**	Citizenship:	**U S**
	Residence:	**1002 Mercedes Ave., Los Altos, CA 94022**		
	Postal Address:	**same as above**		

I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a). I claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)

Country	Application Number	Date of Filing	Priority Claimed Under 35 U.S.C. §119
NONE			[ ] Yes [ ] No

I claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing data of this application.

PRIOR U. S. APPLICATION(S)

Application No.	Filing Date	Status			
NONE		[ ] Provisional	[ ] Patented	[X] Pending	[ ] Regular

I hereby appoint Thomas J. McFarlane, Reg. No. 39,299 , Marek Alboszta, Reg. No. 39,894, Joshua D. Isenberg, Reg. No. 41,088; Rena Kaminsky, Reg. No. 46,818 as my agents with full power of substitution to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith. Direct all correspondence to:

Marek Alboszta
45 Cabot Ave., Suite 110
Santa Clara, CA 95051
Telephone: 408-260-7300
Fax: 408-260-7301.

The attorney docket number for this case is: **NAK-120**.

I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Title 18, §1001 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

INVENTOR SIGNATURE(S)

Dale Buermann 8-30-00

DALE BUERMANN Date

Attorney Docket No: **NAK-120**

POWER OF ATTORNEY BY ASSIGNEE

The undersigned assignee of the entire interest in the attached application for Letters Patent for the invention entitled:

Simultaneous Compensation of Source and Detector Drift in Optical Systems

by virtue of Assignment recorded concurrently herewith hereby appoints Thomas J. McFarlane, Reg. No. 39,299, Marek Alboszta, Reg. No. 39,894, Joshua D. Isenberg Reg. No., 41,088, Rena Kaminsky, Reg. No. 46,818 as its attorneys to prosecute the attached application and to transact all business in the Patent and Trademark Office connected therewith, said appointment to be to the exclusion of the inventor(s) and their attorney(s) in accordance with the provisions of Rule 32 of the Patent Office Rules of Practice.

Please direct all communication relative to said application to the following correspondence address:

Marek Alboszta
Lumen
45 Cabot Ave., Suite 110
Santa Clara, CA 95051
Telephone: 408-260-7300
Facsimile: 408-260-7301

I am duly authorized to sign this instrument on behalf of assignee corporation. I hereby declare that, to the best of my knowledge and belief, title is in the assignee herein, and I affirm review of the Assignment document concurrently submitted and believe that the attached application has been assigned to assignee herein and that assignee therefore has the right to make this Power of Attorney and Exclusion of Inventor(s).

I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

ASSIGNEE: n&k Technology, Inc.

3150 De La Cruz Blvd., Suite 105
Santa Clara, CA 95054

Official Authorized to Act on Behalf of Assignee:

Signature: [signature]
Name: A. Rahim Forouhi
Title: President

8/29/00
Date